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MINIATURE BLACK HOLES GENERATION BY LASER- INDUCED ELECTROMAGNETIC COLLAPSE IN PLASMA

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1. Introduction

In small volume of plasma (approximately 300 ps after laser pulse disruption) the electromagnetic collapse takes place. During which the magnitude of electric fields tensions **E** reaches 1-10's GV/cm and the inductances of magnetic fields **B** are 10's Mgauss. The ion temperature (for protons) increases up to 15 MeV, its pressures increases up to few Gbar. Under this conditions (of relatively "low" electron temperatures about of 1-10 keV only) the state of matter is similar to the state of a miniature black hole. The experimental and theoretical investigations of miniature black holes creation in laser plasmas were carried out. This process is accompanied by exotic quasiparticles generation [1,2] (due to quantum evaporation [3]) and specific space-time effects, which are considered too. The analogous hot plasma with temperature range T=1-5 MeV had been predicted in [4] for "laboratory fireball" produced by an intense laser beam (at a range of intensities peaking at ~ 3 10^{20} W/cm^2). Note, that in practices the generation of analogous system (similar to miniature black hole) had been already realised in [1] without using a super high power laser system. We used a picosecond laser beams (with initial intensities in range ~5 10^{13} –10^{15} W/cm^2) working in mode of optimal filtration (see, e.g. [5]). The detailed numerical calculations based on a 2D-magneto-hydrodynamical model were carried out under concrete experimental conditions. As in [6], we used the mathematical model ZEVS-2D generalized to the case of laser beam interaction with solid targets (Al in the hydrogen atmosphere). The absorption of laser radiation was calculated by taking into account the laser beam propagation in plasma channel.

2. Results of computer simulation

In calculations we assumed that the intensity of laser beams has the time distributions in the focal region (with Gauss distribution over the radius r and the radius of focal spots R = 20 μm): $I(t)= I_{i0} * \exp\{-[10*(t-t_0 -\tau)/\tau]^2\}$, where $\tau \approx 190$ ps on the basis of the laser pulse (so that on the half pulse width we have a strong pulse duration of about 100 ps). For the last prepulse the maximum intensity I_0 = 2.54 10 ^{11} W/cm^2 before the main pulse with maximum intensity I_{10} = 6.35 10 ^{13} W/cm^2 , which starts at t_0 = 7.4 ns after the prepulse. Figures 1-3 correspond to the case of plasma generation by the main laser pulse near the Al-target in ambient hydrogen plasma with gas density $\rho_H = 10^{-3}$ g/cc. In Fig.1 the spatial distribution of magnetic field inductance is shown at the different times. We can see that **B** is decreased with formation fine structures during miniature black hole formation. The ion temperatures and specific internal energy are shown in Figures 2a,b. So we can see that the most interesting physical phenomenon occurs after the switching off (disruption at 53 ps) of our laser beam. Very intense heating of matter in small local region leads to an intense expansion of matter and following rarefaction, which is accompanied by an intense collapse in small volume. Similar process occurs with bubbles in water due to its cavitation. We can give a simple appreciative estimations: $(T/T_0) \approx(\rho_0 /\rho)^{\gamma+1}$, where ρ_0, T_0 is an initial background plasma parameters. For example, if ρ_0 /ρ= 100, for case $\gamma\approx5/3$, T_0=10-100 eV we have T=10^6-10^7 eV. This hydrodynamical processes must be intensified by electrodynamics: an increasing of electric field cases a current self focusing and hence we must have an additional heating of plasma in small volume. We can obtain the matter transition to extreme states with pressures up to a few 100's Mbar at this mode. Thus, we have the extreme states of matter at the stage of an electromagnetic collapse, which is most distinctly observed in our case approximately 300 ps after the laser pulse disruption. Note that in Figures 1,2 the numbers of cells on a calculated grid are indicated along directions **r** and **z**. This grid was nonequidistant and had a small cell size near the target. The maximum radius of considered systems was 0.02 cm and the length about 0.13 cm. In astrophysics it is well known that the behavior of the black holes must be accompanied by hot gas creation moving with the extremely high velocity (up to ¼ c). Our calculation demonstrates the same effect (Fig.3), which is in a good agreement with the observed phenomena: our spinning "tops" have velocities v~ 40 000 km/s (see, e.g. Fig 4).

3. Results of the experimental investigation

Here we demonstrate the observed plate of "censure" (see, Fig.5). It is very important to say, that in miniature black holes as well as in astrophysical black holes the value of light velocity can decreases ($c\to 0$). It means that its mass (and mass of all particles m_p of black holes) must be also very small ($m_p \to 0$, because of in inhomogeneous space-time $m_p \sim c^2$ [7]). This is a main reason why we can generate an exotic particles like as a magnetic monopoles and plasmas (ball lightning) with magnetic charges, at which the Bose-Einstein condensation of different plasma components takes place [8]. In such plasmas we have superconductivity, and superfluidity as well as fine (Fig.6) and crystal-like structures [8]. It is shown that in conditions of black holes its mass must be very small! This last conclusion is an a good agreement with the predictions [9] based on another theoretical model. This means that main reason of hard electromagnetic radiation from black holes must be connected with the nonlinear plasma phenomena [10] then due to mass accretion.

4. SUMMARY

The miniature black holes have been produced in laboratory at first. The explanation of physics generation of exotic quasiparticles and ball lightning have been done.

The present calculations demonstrate only the main trend of the electromagnetic fields evolution at the initial stage of the considered dense plasma with high energy densities. The tensions of the electric and magnetic fields inductance increase up to extremely high values (greater than the characteristic atomic values) due to the microcomulative processes, when the effects of physics of miniature black-holes become very important. Thus, it is evident why the effect of the multiple magnetic monopoles generation was observed in our laser-induced discharges, which was accompanied by matter transition to extreme states, gamma-ray radiation, the ignition of different nuclear reactions and the elementary particle generation.

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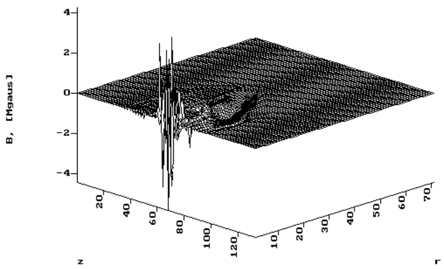


Fig.1a, t = 367.6 ps

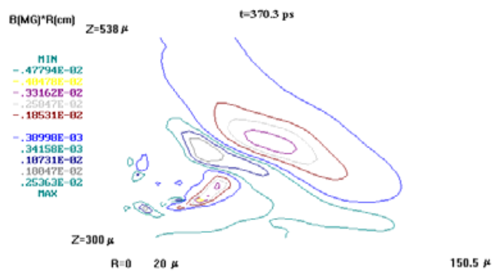
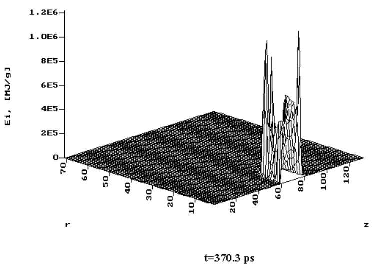


Fig.1b. The product of B[Mgauss]xr[cm].



a)

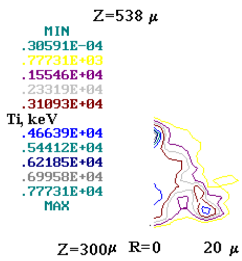


Fig.2, The specific internal energy (a) and ion temperature (b) at t = 370.3 ps

b)

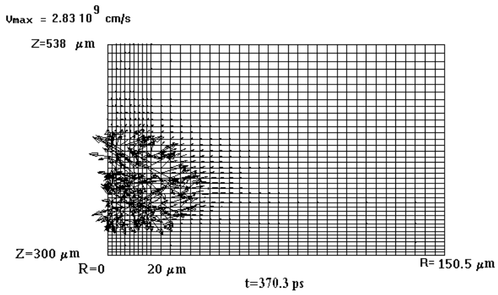


Fig.3

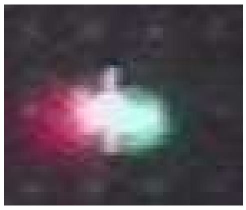


Fig.4

Fig.5

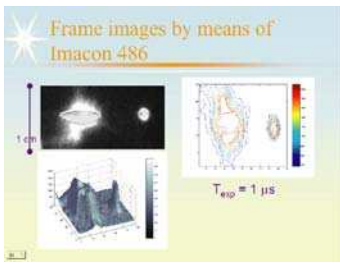


Fig.6